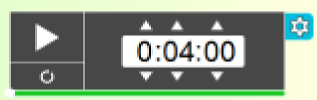
Capacitance	**Charging capacitors**

Learning objectives	**MUST (C)**	Describe how current, p.d. and charge vary in a charging capacitor
	SHOULD (B)	Solve the exponential charging equation for all variables
	COULD (A/A*)	Apply all capacitor equations to solve exam-style questions

STARTER: In a thrilling episode of unmissable* 1980s US drama 'Quincy ME', our hero used an extension cable as a defibrillator. You are a TV physics consultant; watch this footage and comment on any aspects of the physics involved. What is realistic? What is unrealistic? Could they have done it better?

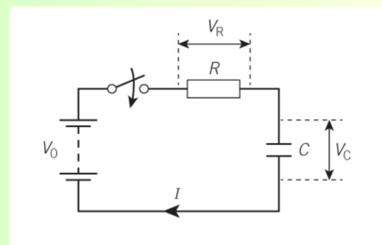
*for fans of weak plots and dodgy acting

Quincy ME



Capacitance	**Charging capacitors**
MUST (C)	Describe qualitatively how and why current, p.d. and charge vary in a charging capacitor
SHOULD (B)	Express I, V and Q quantitatively with respect to time

Recall from last lesson:



The capacitor to the right is uncharged. When the switch is closed, how will the following change?

- Current in the circuit
- V_C
- V_R
- Q for the capacitor

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Potential difference

Charge

Current

V_R

Capacitance	**Charging capacitors**
COULD (A/A*)	Apply all capacitor equations to exam-style questions

1) Summary questions: page 421

2) Try practice questions 1 and 3 on page 424

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21.5

1 The time constant of the circuit is very small because of the small resistance of the copper wires. Therefore the capacitor charges up in a very short time. [1]

2 The current in the circuit and the p.d. across the resistor will both decrease exponentially with respect to time.

3 Start the stopwatch when the switch is closed. Stop the stopwatch when the voltmeter reading has dropped to 37% of its initial reading of V_0. [1]

The time recorded on the stopwatch is equal to the time constant. [1]

4 $V_c = V_0\left(1 - e^{-\frac{t}{CR}}\right) = 3.0 \times \left(1 - e^{-\frac{CR}{CR}}\right) = 3.0 \times 0.63$ [1]

$V_c = 1.896\,\text{V} \approx 1.9\,\text{V}$ [1]

5 $CR = 120 \times 10^{-6} \times 1.0 \times 10^{6} = 120\,\text{s}$ [1]

$V_c = V_0\left(1 - e^{-\frac{t}{CR}}\right) = 3.0 \times \left(1 - e^{-\frac{180}{120}}\right) = 3.0 \times 0.78$ [1]

$V_c = 2.33\,\text{V} \approx 2.3\,\text{V}$ [1]

6 $V_C = V_R$, therefore $V_0\left(1 - e^{-\frac{t}{CR}}\right) = V_0 e^{-\frac{t}{CR}}$ [1]

$\frac{1}{2} = e^{-\frac{t}{CR}}$ [1]

$\ln(0.5) = -\frac{t}{CR}$ [1]

$t = 0.69CR$ [1]

Question	Answer	Marks
1 (a) (i)	Any **two** from: • Correct direction of movement of electrons. • Electrons deposited on Y / removed from X. • An equal number of electrons removed and deposited on plates.	2
1 (a) (ii) (1)	$Q = 40 \times 10^{-6} \times 100$ $= 4.0 \times 10^{-3}$ C $4.0 \times 10^{-3} = 1.6 \times C$ $C = 2.5 \times 10^{-3}$ F	 1 1 1
1 (a) (ii) (2)	Graph starts at origin and has positive gradient. A straight line graph that passes between 1–2 V at 100 s.	1 1
1 (b) (i)	$CR = 4.7 \times 10^{-6} \times 220$ $= 1.03 \times 10^{-3}$ s $4.00 = 6.00\,e^{-\frac{t}{1.03\times10^{-3}}}$ $t = -\ln\left(\frac{4.00}{6.00}\right) \times 1.03 \times 10^{-3}$ time $= 4.2 \times 10^{-4}$ s	 1 1 1
1 (b) (ii)	speed $= \frac{0.100}{4.2\times10^{-4}}$ speed $= 240\ \text{m s}^{-1}$	 1

3 (a)	capacitance $= \frac{\text{charge}}{\text{p.d}}$ or capacitance = charge per unit p.d.	1
3 (b) (i)	$C_{\text{parallel}} = 240\ \mu$F $C_T = \frac{240\times120}{240+120}$ or $C_T = \frac{1}{\frac{1}{240}+\frac{1}{120}}$ total capacitance = 80 μF	1 1
3 (b) (ii)	$E = \frac{1}{2}V^2C$ $E = \frac{1}{2} \times 6.0^2 \times 80 \times 10^{-6}$ energy $= 1.4 \times 10^{-3}$ J	 1 1
3 (b) (iii) (1)	$\frac{6.0}{e} = 2.2$ V (as on graph) Or $6.0 \times 0.37 = 2.2$ V (as on graph) Or At 20 s, $V = 2.2$ V, $\frac{2.2}{6.0} = 0.37 = \frac{1}{e}$	1
3 (b) (iii) (2)	$CR = 20$ $R = \frac{20}{80\times10^{-6}}$ $R = 2.5 \times 10^{5}\ \Omega$	1 1

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